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Method for Driving Halftone Display for a
Liquid Crystal Display

Field of the Invention

5   The subject invention relates to driving methods and control
mechanisms in TFT liquid crystal displays (TFTLDCs). In
particular, the subject invention relates to driving methods and
control mechanisms for TFTLCD's in which the transition for each
color in halftone display is effectively prevented.

Background Art

10   The reduction in size of electronic equipment has been
accompanied by an increase in the use of liquid crystal displays
(LCDs). The LCD is not only used as a computer screen, but also
is used as a television screen, a projection screen, etc.
Utilizing liquid crystal has advantages such as low power
15   consumption due to low driving voltage, and relatively fast
response. It is expected that the field of application of LCDs
will expand in the future.

       Most of the currently used LCDs are of the active matrix
type. The active matrix type means the one in which a separate
20   driving circuit element is provided for each pixel to improve
display characteristics. Active matrix LCDs using thin-film
three-terminal transistors (TFTs) as switching elements are
called TFT liquid crystal displays (TFTLCDs).

In using TFTLCDs to display pictures, it is necessary to provide gray scale data of the picture to the LCD to drive the LCD. Figure 1 shows the construction of the control unit of the TFTLCD. The array/cell portion 1 of the LCD is connected to an
5   X-driver 3 and a Y-driver 5. The X-driver 3, when it is supplied with gray scale data, applies a voltage corresponding to the gray scale data to the cell. The Y-driver 5 is connected to the gate of a switching element, and conducts/does not conduct the voltage applied to the cell by the X-driver 3 at a predetermined time.

10 Gray scale data is supplied to the X-driver by data control unit 10. The data control unit 10 consists of a data control circuit 12 for latching and storing the externally supplied R/G/B data in a buffer, and a timing control circuit 14 for outputting the gray scale data stored in the buffer to the X-driver 3 at a
15 predetermined time. A clock signal is externally supplied to the data control circuit 12 and the timing control circuit 14 to control the timing. A power supply 7 is connected to the X-driver 3, Y-driver 5, and data control unit 10.

To display a picture on an LCD, a voltage corresponding to
20 the gray scale is provided to each pixel of each color. That is, the driving of a pixel is not a simple on-off function, a voltage divided into several levels (gray scales) is provided to adjust the transmissivity of the pixel, so that intermediate color intensity can be displayed. To achieve such control in a color
25 display, R/G/B signal levels are supplied to each pixel. For a display of a 64-level gray scale, 64-step voltage is used, and the voltage for each pixel is applied according to the respective

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gray scale data. Ideally, the same transmissivity can be achieved for all the colors when the voltage corresponding to a particular gray scale is used. The relationship for this is shown in Figure 2. In Figure 2, transmissivity is plotted on the ordinate, and applied voltage is plotted on the abscissa. Applied voltage is determined by the gray scale data. Accordingly, when a certain gray scale n is chosen, the applied voltage Vn is determined by that gray scale. Then, according to the relationship of Figure 2, transmissivity Tn for the gray scale Vn is achieved.

Ideally, the relationship between gray scale, applied voltage, and transmissivity is the same for each of the R/G/B colors. However in actuality, the gray scale and the achieved transmissivity have a slight difference depending on color. This is because the degree of light modulation for the specific twist of the twisted noematic liquid crystal is slightly different depending on wavelength. That is, even though a light passes through a liquid crystal layer in a similarly twisted state, the degree of the modulation given to the passing light is wavelength dependent, and thus the scattering of brightness that occurs for a given gray scale is color dependent. This is shown in Figure 3. The transmissivity of blue (B) is higher than that of both red (R) and green (G) for the same voltage over a wide range of applied voltage. That is, since the relationship between gray scale and applied voltage for each color is unique, the transmissivity of blue (B) is greater even if each color is selected with the same gray scale and the same voltage is applied in the displaying of intermediate colors. Thus, the correlation

between transmissivity and applied voltage (hereinafter referred to as transmissivity/applied voltage characteristics) has a color (wavelength) dependency. If the displaying is performed without providing any correction, the gradation of color translates to

5 blue more than called for by the halftone data, and the picture on the whole takes on a bluish hue. Figure 4 shows this state represented by a chromaticity diagram. Figure 4 shows that L63 should be a white color state if an ideal state could be realized, but in actuality, L0, or a shift to blue, occurs

10 because of the wavelength dependency of the transmissivity/applied voltage characteristics.

Various methods have been proposed for correcting the above problem. These methods are roughly divided into (1) methods for making the correction by the modification of the structure of

15 LCD, and (2) methods for making the correction by using electric control.

A typical example of the first category (1) is the adoption of a multi-gap structure. A multi-gap structure is a structure in which the thickness of the color filter of the pixel of each

20 color of R/G/B varies. That is, the thickness (gap) of the liquid crystal sealing portion is changed to achieve the matching of the transmissivity/applied voltage characteristics for each color. However, implementation of a multi-gap structure is accompanied by difficulties in the manufacturing process.

25 Problems occur in the adjustment of the thickness of the color filter, and in the uniformization of the gap between the two glass substrates forming the liquid crystal cell. Yield is

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effected by these difficulties causing an increase in manufacturing cost.

As an example of the second category (2), is a method in which the reference voltage (gray scale voltage) given to the data driver is tailored to the characteristics for each color. This method can compensate for the color dependency of the transmissivity/applied voltage characteristics. However, the circuits needed to independently control the reference voltages, raise the cost and cause difficulties in the implementation. Another method that falls within this second category, is to use the voltage for one of the colors of R/G/B as a reference voltage, and use offset voltages for each of other colors. This method has the same problems as the method in which the reference voltages are separately applied, and in addition, cannot accomplish desired effect if the gradients of the curves showing the transmissivity/applied voltage characteristics of R/G/B vary with applied voltage. That is, in accordance with the offset voltage method, correction is carried out by applying a uniform offset voltage for all applied voltages, and thus the correction cannot be effectively performed unless the gradients of the curves showing the transmissivity/applied voltage characteristics are the same over the whole applied voltage range.

Japanese Published Unexamined Patent Application No. 01-101586 discloses a technique in which different liquid crystal driving voltage levels are set for each of the colors, and that level is applied to each pixel. Japanese Published Unexamined Patent Application No. 03-6986 discloses a technique in which the

driving voltage is made to vary a predetermined voltage from color to color to obtain uniformity in transmissivity. Japanese Published Unexamined Patent Application No. 03-290618 discloses a technique in which a similar object is accomplished by

5   independently inputting a gray scale control signal for each color.

Therefore, first object of the subject invention is to provide a driving method for a TFTLCD in which the dependency on color of the transmissivity/applied voltage characteristics is

10   effectively corrected.

A second object of the subject invention is to realize the effective correction using a very simple method which enables the above described correction to be made without increase in complexity of the control method, and the restrictions on the

15   implementation by addition of circuits.

Summary of the Invention

In accordance with the present invention, the above described problems are solved by gray scale data (a bit string for a color liquid crystal display) wherein the data control means includes a

20   computing circuit for performing an addition or subtraction of the gray scale related to at least one color to generate a corrected gray scale, and also includes delay means for delaying the outputting of the uncorrected gray scales, during the time which the gray scale of the one color is being corrected.

Brief Description of the Drawings

Figure 1 is a diagrammatic view of the driving circuit for TFTLCD according to the background art;

Figure 2 is a graph showing the transmissivity/applied voltage characteristic in an ideal color LCD;

Figure 3 is a graph showing the transmissivity/applied voltage characteristic of the color LCD in the background art;

Figure 4 is a chromaticity diagram showing an example of the color transition of the color LCD in the background art;

Figure 5 is a diagrammatic view of the data control unit in the driving circuit for TFTLCD according to the subject invention;

Figure 6 is a diagrammatic view of the condition determination table in the data control unit according to the subject invention;

Figure 7 is a diagrammatic view of the addition/subtraction table in the data control unit according to the subject invention;

Figure 8 is a circuit for implementing by hardware the condition determination and the condition determination table in the data control unit according to the subject invention; and

Figure 9 is a graph showing the transmissivity/applied voltage characteristic corrected by the driving circuit for TFTLCD according to the subject invention.

Preferred Embodiment

5   The subject invention can be realized by improving the data control unit 10 of Figure 1 as is shown in Figure 5. In the background art, the data control unit consists only of a latch and a buffer. However, in the subject invention, the gray scale data related to a color, that is to be corrected, is temporarily

10   inputted to a computing circuit. An addition or subtraction operation is applied to that gray scale data to shift it by one or more gray scale levels, to thereby achieve transmissivity equivalent to the other colors which are not to be corrected.

       In Figure 5, the color to be corrected is blue (B), and the

15   colors which are not to be corrected are red (R) and green (G). The gray scale data related to R or G are shown by R0 to R5 or G0 to G5 in Figure 5.

       A portion 20 to which gray scale data related to R and G are inputted includes a data latch circuit 22 and a buffer circuit

20   26, like that in the data control unit in the background art. However, in addition to the data control unit in the background art, it includes a delay circuit 24. This is to compensate for the time during which the gray scale data B0 to B5 related to B is operated on by a computing circuit 32 in accordance with a

25   condition determination table 36, as described later. The delay

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circuit 24 thereby assumes the outputting of the R and G gray
scale data to the driver with the same timing as the corrected B
gray scale data.

The gray scale data B0 to B5 for blue is a bit string for
5   representing a 64-level gray scale. It is comprised of a bit
string (B0, B1, B2, B3, B4, B5). For instance, if the gray scale
is "4", (B0, B1, B2, B3, B4, B5)=(001000), and if the gray scale
is "28", (B0, B1, B2, B3, B4, B5)=(001110). The same applies for
R0 to R5 or G0 to G5 which are the gray scale data for reg or
10   green, respectively.

Circuit 30 is for adjusting the Blue gray scale data B0 to
B5. To accomplish this, the gray scale data related to Blue is
first supplied to a computing circuit 32. In the computing
circuit 32, the gray scale data for blue is reduced, for
15 A instance, by zero to four levels in comparison with the grey scale
data for red and green. By correcting gray scale data in this
A way, results in matching ~~with~~ the transmissivity of blue to Red that of
and Green.

Further, the gray scale data for Blue is also supplied to a
20   condition determination table 33. The condition determination
A table 33 determines the amount of the adjustment of the gray scale
data. A diagrammatic representation of the condition
determination table 33 is shown in Figure 6. As shown,
conditions A to C, corresponding to various gray scale levels,
25   are set in the condition determination table 33. The condition
corresponding to a gray scale is outputted from the condition

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determination table 33 to an addition/subtraction table 34. The
addition/subtraction table 34 has the function of setting the
actual amount of the addition or subtraction. A diagrammatic
representation of the addition/subtraction table 34 is shown in

5   Figure 7. That is, the addition/subtraction tables set the
amount to be added or subtracted according to the condition
provided from the condition determination table 33. The amount
of the addition or subtraction to correct the gray scale is
supplied to the computing circuit 32.

10   The condition determination table 33 and the
addition/subtraction table 34 can be implemented by software.
The condition determination table can also be implemented by
hardware by using the logic circuit shown in Figure 8. To
implement the specific conditions represented in Figure 6, the

15   gray scale data B0 to B5 are inputted to the logic circuit as
shown. The gray scale data of B2 to B5 are inverted and inputted
to an AND circuit 101 to create a condition corresponding to
condition A in Figure 6 for gray scale levels 0 to 3. Similarly,
the gray scale data B0, B2 to B5 for gray scale levels 61 to 63

20   corresponding to condition A is inputted into AND circuit 102.
The outputs of the AND circuit 101 and the AND circuit 102 are
inputted to an OR circuit 106, and the condition A is outputted
by circuit 110. AND circuit 103 and AND circuit 104 are circuits
for generating condition B. Inputted to ANDs 103 and 104 is an

25   output 122 separately created in a group of logic circuits 120,
to thereby output the condition B for desired gray scale data
levels 4 to 10 and 54 to 60. If there is no output from OR
circuits 106 and 107, condition C is set. In this case, an

output is provided by an AND circuit 108 to the circuit 110 to
achieve the generation of condition C. Conditions A, B, and C
are outputted from Q1 to Q3 of the circuit 110.

5   Operation of the circuit 30 to which gray scale data for blue
is inputted, and of the circuit 20 to which gray scale data
related to Red and Green are inputted is as follows. When a gray
scale level "2" is received, or (B0, B1, B2, B3, B4, B5)=(010000)
is inputted, the input to the display is determined by the
condition determination table 33. As shown in Figure 6, in the
10   condition determination table 33, the condition A is outputted to
the addition/subtraction table 34, and thereafter, in the
addition/subtraction table 34, "0" is outputted to the computing
circuit as the addition or subtraction amount as shown in Figure
7. Accordingly, the gray scale "2" is provided unconnected to
15   the X-driver via a buffer circuit 36. The above described
processing causes a predetermined delay. Thus, the gray scale
data for Red and Green corresponding to the gray scale data
related to Blue are delayed for time taken for the processing by
a delay circuit 24. As a result, the gray scale data related to
20   B is outputted from the buffer circuit 36 to the X-driver is
synchronized with the gray scale data for Red and Green for
simultaneous output from the buffer circuit 26 to the X-driver.

       Where the gray scale data level is "20," or the grey scale
level signal (B0, B1, B2, B3, B4, B5)=(001010), the condition
25   determination table 33 provides condition C signal to the
addition/subtraction table 34 as shown in Figure 6. In response,
the addition/subtraction table 34 provides a signal to the

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computing circuit to subtract four grey scale levels (the amount as shown as -4 in Figure 7). Accordingly, the gray scale level "20" is corrected by the computing circuit 32 to a gray scale level "16" (20-4=16) which level is provided to the X-driver via the buffer circuit 36. In this way, corrections are made to the transmissivity/applied voltage characteristics where, as shown in Figure 3, they are not uniform for each color.

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Figure 9 shows the affect the correction of the present invention has on the transmissivity/applied voltage characteristics. In this figure, the ordinate indicates transmissivity and the abscissa indicates gray scale level all of R/G/B, the same transmissivity is achieved for the same gray scale level. Thus, it is seen that the problem of the subject invention of effectively correcting the difference in the dependency of the transmissivity/applied voltage for each color has been solved.

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In accordance with the subject invention, the difference in the dependency of the transmissivity/applied voltage characteristics for each color can be effectively compensated for. Further, the amount of the adjustment can be varied with the grey scale level for accurate compensation.

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With the method of the subject invention, only an additional circuit such as a computing circuit, is needed to effectively correct the differences in the transmissivity/applied voltage characteristics for colors. The above correction is made while avoiding the problems in complexity of control methods in the

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background art. That is, to implement the subject invention, only a condition determination circuit is needed in the data control circuit. It is not necessary to change the structure of the X-driver or the structure of the cell.

5   Although, in this embodiment, the gray scale data related to B has been made to match the gray scale data related to R and G by performing a subtraction thereof, it should be self evident to those skilled in the art that an addition of the gray scale data related to Red and Green can be used to match the gray scale data
10   for those colors with the gray scale data related to Blue using the teaching of the present invention. Therefore, it should be understood that many changes can be made in the described embodiment without departing from the spirit and scope of the present invention.

Claims

We claim:

Claim 1

1. A liquid crystal color display comprising:
2.   a) a display cell,
3.   b) driver means connected to said display cell for driving
4. the display cell with sets of grey scale data signals each signal
5. for a different color, and
6.   c) data control means for receiving gray scale data signals
7. related to the setting of a gray scale for the display cell and
8. outputting said gray scale data signals to said driver with a
9. predetermined timing, wherein said data control means includes:
10.   i) computing means for correcting the gray scale data
11. signals to at least one color to a different gray scale level to
12. compensate for differences in transmission between the colors,
13. and
14.   ii) buffer means for delaying the gray scale signals
15. related to unconnected colors for the time during which said
16. corrected gray scale data signal is being corrected.

Claim 2

1. A liquid crystal color display of Claim 1 wherein: said data
2. control means comprises adjusting means for varying the amount of
3. correction accorded to the gray scale data signals for said at
4. least one color.

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